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Heavy metal contamination of water bodies, soils and vegetables in peri-urban areas: A case study in Bangaluru

L.R. Varalakshmi and A.N. Ganeshamurthy
Division of Soil Science and Agricultural Chemistry
Indian Institute of Horticultural Research, Hessaraghatta
Bangalore- 560 089, India
E-mail : lrvaral@iihr.ernet.in

ABSTRACT

A study was conducted in peri-urban Bangaluru (where city wastewater from four water bodies, *viz*., Bellandur, Varthur, Byramangala and Nagavara tanks, is being used for cultivation of vegetable crops) to assess heavy metal contamination in water, soil and vegetable samples. Analyses revealed that concentration of cadmium (Cd) and chromium (Cr) in waters from all the tanks exceeded recommended levels of 0.01 and 0.1 mg/l, respectively, while content of lead (Pb) and nickel (Ni) are within safe limits. Concentration of Cd was highest in the water of Bellandur tank (0.039 mg/l) and of Cr was highest in the water of Byramangala tank (0.311 mg/l). Bellandur and Varthur tanks were found highly contaminated with Cd, Pb and Ni. Mean concentration of heavy metals in soils receiving sewage water from the four tanks ranged from 1.92 to 2.9 mg/kg for Cd, 47.04 to 68.12 mg/kg for Pb, 35.08 to 92.78 mg/kg for Cr and 48.2 to 57.3 mg/kg for Ni. Cd and Pb content were highest in soils around Varthur and Bellandur tanks, while, mean concentration of Cr was highest in soils around Byramangala tank. Similar trends were observed for heavy metal content in vegetables. Among the vegetables studied, leafy vegetables accumulated higher concentration of heavy metals, followed by root vegetables. Cd concentration in all the vegetables grown around Varthur and Bellandur tanks exceeded the safe limit prescribed under Prevention of Food Adulteration Act (PFA 1954). Pb and Ni concentration exceeded safe limits in all the vegetables in all the tank areas studied.

Key words: Heavy metals, peri-urban, water bodies, soils, vegetables

INTRODUCTION

Contamination of environment with the toxic heavy metals has become one of the major causes for concern for human health in both developing and the developed countries. Heavy metals in surface-water bodies, groundwater and soils can come from either natural or anthropogenic sources. Currently, anthropogenic inputs of metals exceed natural inputs due to increased industrialization and urbanization. Industrial wastes, atmospheric fall-outs from crowded cities and other domestic waste figure among the major sources of heavy metals in urban sewage (Sorme and Lagervist, 2002). Wastewater in natural streams or storm-water drains from the cities is let either into lakes or reservoirs in peri-urban areas, causing heavy metal contamination of these water bodies. Due to increased demand for water for the multiple needs of our fast-growing cities, the small and marginal farmers in peri-urban areas are forced to use contaminated water from water bodies for their needs like cultivation of vegetables. Soils receiving such water accumulate heavy metals to a varying degree depending on soil properties, heavy metal concentration in water and frequency of irrigation (Lokeshwari and Chandrappa, 2006). Excess levels of metals in soil, water and air may pose health risk to humans and endanger ecosystems. Though not essential for plant growth, these metals are absorbed by crops along with other essential plant nutrients and may have adverse effect on soil, plants, animals and humans.

Bellandur, Varthur, Byramangala and Nagavara tanks are important water bodies of Bangaluru city forming a part of the city's drainage system. Untreated and partially-treated domestic sewerage and industrial wastewater from different parts of the city are drained into these tanks. Important industries in Bangaluru such as IT companies, Public Sector Units, small-scale units (like plating and smelting industries), garment factories, distilleries, etc. release wastewater into storm-water and sewerage drains. Ultimately, these waste waters find their way into tanks. The present study was aimed at assessing levels of contamination due to four major toxic, heavy metals, *viz.* Cd, Pb, Cr and Ni in the above-mentioned water bodies, and in the vegetables grown and soils irrigated with contaminated water from these tanks.

MATERIAL AND METHODS

Study site

Survey was conducted during 2005-2008 in villages surrounding Bellandur tank (Bellandur, Panatur and Yamalur), Varthur tank (Varthur, Ramagondanahalli and Siddapura), Byramangala tank (Byramangala, Chikkondanahalli and Parasinapalya) and Nagavara tank (Rampura and Bilisiwale). All these villages fall within 2 km. radius from the tank and farmers irrigate vegetable crops using this water by direct pumping. A vegetable farm located away from these tanks that used uncontaminated underground water through borewell was used as the control.

Sampling and sample preparation

Water samples from all the four tanks and borewell of the uncontaminated site were collected in washed and thoroughly rinsed polyethylene bottles. The lids were closed upon adding a few drops of Toluene to arrest microbial activity. Samples were then brought to the laboratory and stored in the refrigerator at $4^{O}C$ for further analysis. Surface-soil samples (0-15cm) from farmers' fields were collected in clean plastic bags. These were dried at room temperature, and ground using a clean mortar and pestle, and passed through 2.0 mm sieve.

Samples of six common vegetables grown using tanks waters and representing two leafy vegetables viz. amaranth (*Amaranthus tricolor* L) and Indian spinach – *palak (Beta vulgaris var. Bengalensis Roxb.),* two root vegetables viz. carrot (*Daucus carota* L.) and radish (*Raphanus sativus* L.) and two fruit-vegetables viz. tomato (*Lycopersicon esculentum)* and french bean (*Phaseolus vulgaris* L.) were collected from three fields in brown paper bags and brought to laboratory for analysis. The samples were sequentially washed with mild detergent solution, 0.1% HCl, distilled water and , finally, with double distilled water. Excess water was dried with blotting paper. The vegetables were cut into small pieces, dried at room temperature and, later in the oven, at $60^{o}C$. Dried vegetable samples were powdered in a laboratory mixer. Soil and vegetable samples from uncontaminated field (Control) were also collected and processed similarly. Soil and vegetable samples were digested with a tri-acid mixture (HNO_3, $HClO_4$ and H_2SO_4 in 5:1:1 ratio) (Allen *et al*, 1986). Total heavy metal content in water samples, digested soil and vegetable samples was estimated using Perkin Elmer Flame Atomic Absorption Spectrophotometer. Standard deviation in each result was workedout.

RESULTS AND DISCUSSION

Heavy metal content

In tank waters

Mean heavy metal concentration (mg/l) of water from the four water bodies is shown in Table 1. It ranged from 0.014-0.039 mg/l for Cd, 0.039-0.075 mg/l for Pb, 0.120-0.311 mg/l for Cr and 0.027-0.042 mg/l for Ni. Mean Cd, Pb, Cr and Ni content in borewell waters of uncontaminated site was 0.002; below detectable level; 0.015 and 0.0016 mg/l respectively. As per standard guidelines for irrigation water (Pescod, 1992), mean Cd and Cr content in all the tanks exceeded recommended levels of 0.01 and 0.1 mg/l respectively, while content of Pb and Ni was within safe limits. Levels of all the four heavy metals were within safe limits in borewell waters from the uncontaminated site.

Table 1. Heavy metal concentration (mg\l) in various water bodies in peri-urban Bangaluru

Source of irrigation water		Cd	Pb	Cr	Ni
Varthur tank					
No: 36	Mean	0.033	0.075	0.289	0.039
	Minimum	0.019	0.030	0.096	0.012
	Maximum	0.043	0.136	0.513	0.101
	SD	0.009	0.039	0.189	0.036
Bellandur tank					
No: 36	Mean	0.039	0.065	0.291	0.042
	Minimum	0.028	0.022	0.080	0.015
	Maximum	0.05	0.084	0.538	0.097
	SD	0.008	0.025	0.198	0.033
Byramangala tank					
No: 36	Mean	0.022	0.059	0.311	0.040
	Minimum	0.008	0.025	0.098	0.015
	Maximum	0.038	0.088	0.601	0.100
	SD	0.011	0.024	0.215	0.03
Nagavara tank					
No: 24	Mean	0.014	0.039	0.120	0.027
	Minimum	0.010	0.017	0.039	0.008
	Maximum	0.016	0.060	0.138	0.056
	SD	0.002	0.016	0.067	0.018
Borewell of Uncontaminated site					
No: 12	Mean	0.002	BDL	0.015	0.0016
	Minimum	0.001	BDL	0.008	0.001
	Maximum	0.003	BDL	0.025	0.003
		0.0008	-	0.007	0.0008
Safe limit*		0.01	0.5	0.1	0.2

*Source: Pescod, 1992; No: number of samples; BDL: Below Detectable Level
SD = Standard Deviation

Table 2. Heavy-metal concentration (mg/kg) in soils receiving sewage water from various water bodies in peri-urban Bangaluru

Soil samples		Cd	Pb	Cr	Ni
Near Varthur tank					
No: 36	Mean	2.90	68.12	56.50	57.3
	Minimum	1.80	45.70	45.20	36.2
	Maximum	3.60	95.30	81.30	81.3
	SD	0.70	18.70	14.64	19.9
Near Bellandur tank					
No: 36	Mean	2.38	64.90	51.80	45.7
	Minimum	1.52	48.70	38.80	27.6
	Maximum	3.20	81.20	52.50	72.0
	SD	0.67	12.50	13.40	14.5
Near Byramangala tank					
No: 36	Mean	2.06	55.02	92.78	46.1
	Minimum	1.30	35.60	74.30	38.5
	Maximum	2.90	65.80	112.30	58.6
	SD	0.71	7.67	14.05	79.0
Near Nagavara tank					
No: 24	Mean	1.92	47.04	35.08	48.2
	Minimum	1.60	36.70	26.90	37.4
	Maximum	2.30	58.20	43.50	57.6
	SD	0.25	7.67	7.83	9.09
Uncontaminated field					
No: 12	Mean	0.90	39.60	34.20	34.9
	Minimum	0.62	31.50	28.50	25.0
	Maximum	0.81	51.00	45.00	46.2
	SD	0.22	7.47	6.31	8.00
Safe limit*		1.6-3.0	90-300	100-120	48-75

*Source: Kabata-Pendias and Pendias (1984); No: number of samples
SD = Standard Deviation

Cadmium

Concentration of Cd was maximum in Bellandur (0.039 mg/l), followed by Varthur (0.033 mg/l). Byramangala tank water contained 0.22 mg/l Cd while Nagavara tank water contained the lowest (0.014 mg/l).

Lead

Levels of Pb (0.5 mg/l) were found not to exceed the limit prescribed in all the tanks. Varthur tank recorded highest Pb level (0.075 mg/l) followed by Bellandur (0.065 mg/l). Nagavara tank had the lowest Pb level (0.039 mg/l).

Chromium

Of all the heavy metals examined, Cr content was maximum in all the tank waters. Byramangala tank recorded the highest concentration (0.311 mg/l) followed by Bellandur tank (0.291 mg/l).

Nickel

Ni concentration was found to be maximum in Bellandur tank (0.042 mg/l), followed by Varthur tank (0.039 mg/l).

Among the four tanks, Bellandur and Varthur were found to be highly contaminated with Cd, Pb and Ni. This could be due to a high concentration of plating and smelting units, automobile repair units and IT units around drainage lines of these tanks. Stormwater carries a heavy load of these metals into water bodies (Lokeshwari and Chandrappa, 2006). Higher levels of Cr in Byramangala tank can be attributed to wastewaters and effluents released from chromium electroplating industries in its surrounding areas. Mean Cd, Cr and Ni content in waters of the four tanks was 20-25 times higher than borewell water from the uncontaminated site.

In soils

Concentration of heavy metals in agricultural soils receiving sewage waters from these tanks ranged from 1.92 -2.90 (mg/kg) for Cd, 47.04-68.12 (mg/kg) for Pb, 35.08-92.78 (mg/kg) for Cr and 48.2-57.3 (mg/kg) for Ni (Table 2). Mean Cd, Pb, Cr and Ni content of uncontaminated site was 0.90, 39.6, 34.2 and 34.9 mg/kg, respectively.

Cadmium

Cd content was highest (2.90 mg/kg) in soils around Varthur tank, followed by soils close to Bellandur tank (2.38 mg/kg). Soils near Byramangala and Nagavara tank contained 2.06 and 1.92 mg/kg Cd, respectively. Cd content in soils of all the tank areas studied was found to approach threshold level (1.6-3.0 mg/kg). Highest concentration of Cd in soils around Varthur and Bellandur tanks may be attributed to the long-term use of contaminated tank waters for irrigation (Sharma *et al*, 2008).

Lead

Mean concentration of Pb was also highest in soils around Varthur and Bellandur tanks (68.12 and 64.9 mg/kg, respectively), followed by soils close to Byramangala (55.02 mg/kg) and Nagavara tanks (47.04 mg/kg). Levels of Pb in soils near Varthur and Bellandur were very close to the threshold level of 90-300 mg/kg (Kabata-Pendias and Pendias, 1984). Maximum Pb content in these soils was 95.3 and 81.2 mg/kg, respectively. High levels of Pb in these soils can be ascribed to their proximity to the national highway and ring road (where traffic density has increased multifold in the past decade), atmospheric deposition from this traffic, and prolonged use of tank water. Sharma *et al* (2009) also reported increased levels of Pb in soils near highways in Varanasi.

Chromium

Mean concentration of Cr was highest in soils near Byramangala (92.78 mg/kg), followed by Varthur (56.5 mg/kg) and Bellandur (51.8 mg/kg). Mean concentration of Cr was highest in soils near Byramangala (92.78 mg/kg). This might be due to the long-term use of tank water contaminated with effluents discharged from chromium electroplating industries.

Nickel

Ni content was highest in soils near Varthur (57.3 mg/kg), followed by soils near Nagavara tank (48.2 mg/kg). This may be due to effluents discharged from electroplating industries around the tank.

Values for mean concentration of Cd in Bellandur and Varthur tank soils were similar to that reported from Varanasi soils (2.8 mg/kg) by Sharma *et al* (2007), but were lower than Cd content (30.72 mg/kg) reported by Gupta *et al* (2008) for soils of Titagarh, West Bengal. Mean Pb, Cr and Ni values observed in this study were higher than that in soils of Varanasi but lower than that in Titagarh soils.

In vegetables

Cadmium

Metal concentration in vegetables varied in different tank areas. Mean concentration of Cd ranged from 2.44-6.90 mg/kg in vegetables from Varthur tank, 2.4-7.23 mg/kg from Bellandur tank, 0.69-1.62 mg/kg from Byramangala tank and 0.48-1.87 mg/kg from Nagavara tank (Fig 1). Cd content of vegetables collected from the uncontaminated site ranged from 0.12-1.14 mg/kg. The data showed very high content of Cd in almost all the vegetables grown near Bellandur and Varthur tanks, exceeding the PFA safe limits of 1.5 mg/kg (Awasthi, 2000). This may be due to the high concentration of Cd in tank waters and their long-term use for vegetable cultivation. In the other two tank areas, only amaranth and spinach contained levels exceeding 1.5 mg/kg. These leafy vegetables accumulated maximum levels of Cd, followed by the root vegetables, carrot and radish. Tomato and French bean accumulated the lowest amounts which could be due to selective retention of heavy metals in different parts of the plant. Jidesh and Kurumthottical (2000) observed that the shoot portion of chilli recorded highest cadmium content followed by roots; least uptake of Cd was noted in the fruit. Further these differences may be due, in part, to genotypic variations between species for absorption or translocation of toxic metals (Michalska, 1997). Cd content of vegetables in Varthur and Bellandur was 6-16 and 6-20 folds higher, respectively than that in vegetables from the uncontaminated site.

Lead

Pb concentration in vegetables varied from 3.12-10.32 mg/kg near Varthur tank, 7.24-16.8 mg/kg in Bellandur tank area, 4.83-9.83 mg/kg in Byramangala tank area and 2.56-9.48 mg/kg in Nagavara tank area (Fig 1). Mean Pb concentration of vegetables grown in uncontaminated soils ranged from 0.73-1.35 mg/kg. PFA safe limit for Pb is 2.5 mg /kg (Awasthi, 2000). Elevated levels of Pb in vegetables grown near Varthur and Bellandur may be attributed to long-term use of tank waters, high levels of Pb in these tanks, proximity of the field to highway and due to atmospheric deposition. Accumulation of Pb in vegetables was: leafy

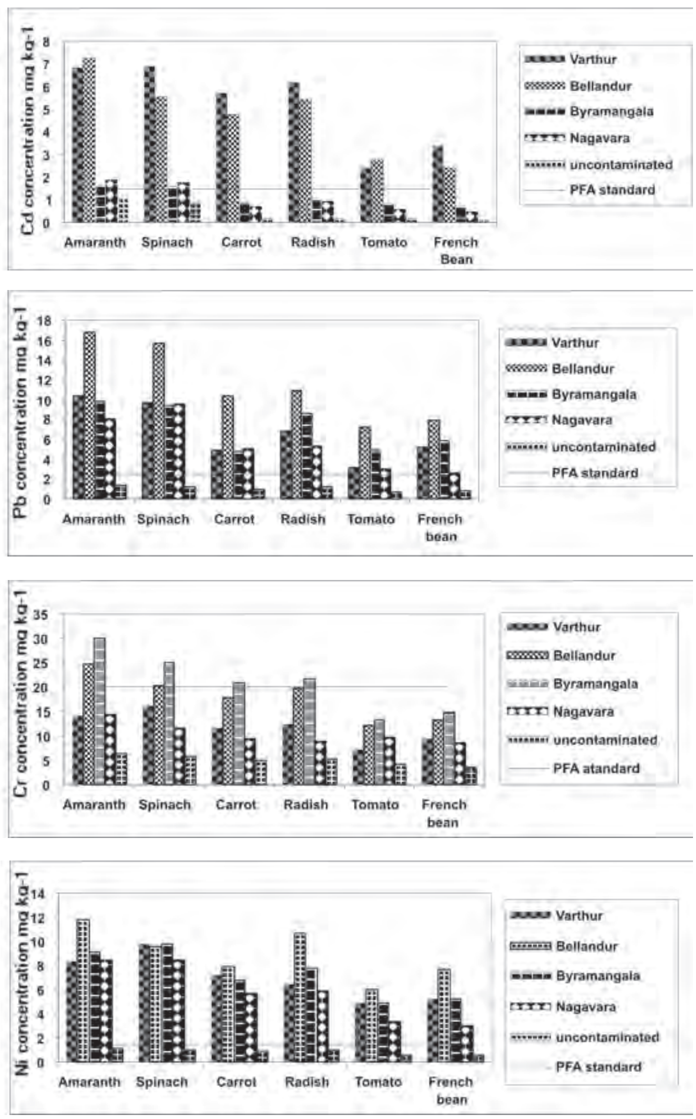

Fig 1. Heavy-metal content in vegetables grown using contaminated tank waters in peri-urban Bangalore

vegetables > root vegetables > fruit vegetables. Pb content of vegetables in Varthur and Bellandur tank was 5-8 fold and 10-12-fold higher, respectively, than those grown in the uncontaminated site.

Chromium

Mean Cr concentration in vegetables ranged from 7.36-16.0, 12.3-24.8, 13.4-30.0 and 8.5-14.5 mg/kg near Varthur, Bellandur, Byramangala and Nagavara tanks, respectively (Fig 1). Cr levels in vegetables from the uncontaminated site ranged from 3.75 -6.50 mg/kg. Highest concentration of Cr was found in vegetables grown around Byramangala tank. Excepting tomato and French bean, all the vegetables contained Cr levels exceeding the PFA safe limit of 20 mg/kg (Awasthi, 2000). Mean Cr concentration of vegetables grown near Varthur and Nagavara tanks was well within safe limits while that in amaranth and spinach grown near Bellandur was slightly above the safe limit. Cr concentration in carrot and radish near this tank was close to the threshold level. Effluents discharged into Byramangala tank from the surrounding industrial units and long-term use of the tank waters for vegetable cultivation may have caused higher levels of Cr to build up in vegetables near Byramangala tank (5-fold higher than in vegetables from the uncontaminated site).

Nickel

Mean Ni concentration in all these vegetables grown near the tanks exceeded the PFA safe limit of 1.5 mg/kg (Awasthi, 2000) for human consumption. Levels in vegetables near Bellandur tank were higher than in other tank areas. Mean Ni concentration in vegetables ranged from 4.94-9.78 mg/kg near Varthur tank, 6.0-11.8 mg/kg near Bellandur tank, 4.89-9.82 mg/kg near Byramangala tank and 3.0-8.5 mg/kg near Nagavara tank (Fig 1). Ni concentration of vegetables grown in the uncontaminated site ranged from 0.59-1.15 mg/kg. Mean Ni concentration was: leafy vegetables > root vegetables > fruit vegetables. Mean Ni concentration in vegetables near Bellandur tank was about 10-fold higher than in vegetables from the uncontaminated site. Similar results were reported by Gupta *et al*, (2008).

Average Cd level in vegetables grown around different tank areas in the present study (0.48-7.23 mg/kg) was higher than that in vegetables from Varanasi (0.5-4.36 mg/kg), and lower than that in Titagarh, West Bengal. Average Pb content (2.56-16.80 mg/kg) and Cr (8.50-30.0 mg/kg) content of vegetables in the present study was comparable to Pb (3.09-15.74 mg/kg) and Cr (5.37-27.83 mg/kg) content in vegetables from Varanasi, but 3-4 fold lower than that in vegetables from Titagarh (21.59-57.63 mg/kg of Pb, and 34.83-96.30 mg/kg of Cr). Mean concentration of Ni in vegetables observed in the present study (3.00-11.8 mg/kg) was slightly higher than that in vegetables from Varanasi (1.81-7.57 mg/kg) (Sharma *et al*, 2007), but several-fold lower than that observed (42.79-62.70 mg/kg) in Titagarh, West Bengal (Gupta *et al*, 2008).

Thus, it can be concluded that waters of four major water bodies of Bangaluru were contaminated with heavy metals, especially Cd and Cr. Though levels of heavy metals in the soil were within safe limits, levels in vegetables far exceeded the official Indian standards (Awasthi, 2000). Leafy vegetables accumulated highest concentrations, followed by root and fruit vegetables. Vegetables grown with water from Varthur and Bellandur tanks accumulated higher concentrations of Cd, Pb and Ni, whereas, those grown with water from Byramangala tank accumulated very high levels of Cr. High levels of heavy metals in tank waters, soils and vegetables can be attributed to discharge of municipal and industrial wastewaters into these water bodies. Regular monitoring of heavy-metals in water bodies, soils and vegetables in peri-urban areas is required to prevent build-up of these toxic metals in the food chain leading to potential health hazards.

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